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WATER QUALITY CONTROL STUDY. POWDER RIVER BASIN, KAYCEE UNIT, WYOMING

Federal Water Pollution Control Administration
Denver, Colorado

February 1966

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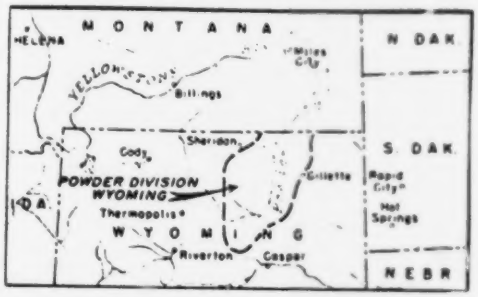
WATER QUALITY CONTROL STUDY

POWDER RIVER BASIN
KAYCEE UNIT
WYOMING

A STUDY OF THE NEED AND VALUE OF STORAGE FOR WATER QUALITY CONTROL



U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
REGION VIII
DENVER, COLORADO

February 1966

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P 87 Water quality control study, Powder River basin, Kaycee unit, Wyo., Study of need and value of storage for water quality control [with bibliography]. Feb. 1966. [Prepared at request of and in cooperation with Reclamation Bureau, Region 6, Billings, Mont.] Environmental Protection Agency

(no LC number)

WATER QUALITY CONTROL STUDY

POWDER RIVER BASIN
KAYCEE UNIT
WYOMING

ABSTRACT

A survey has been made of the Powder River Basin and the Kaycee Unit in particular which determined that waters of the area are at times highly mineralized. Because of the lack of beneficial water users below the project, storage for streamflow regulation for the purpose of water quality control has not been recommended.

Prepared at the request of and in cooperation with the Bureau of Reclamation, Region 6, U. S. Department of the Interior, Billings, Montana

U. S. Department of Health, Education, and Welfare
Federal Water Pollution Control Administration
Region VIII

February 1966

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INTRODUCTION

Request and Authority

The Bureau of Reclamation, Region 6, Department of the Interior, in a letter dated 15 March 1965, requested the Public Health Service, Department of Health, Education, and Welfare, to participate in the Bureau's planning of the Kaycee Unit as set forth in the Federal Water Pollution Control Act, as amended (33 U.S.C. 466 a(b)).

Purpose and Scope

This study is to access the probable effects of the proposed project on the water quality in the Powder River and in the project reservoir; to ascertain the benefits or harm resulting from changes in water quality; to assess the suitability of the water for proposed water uses; and to determine the need for and the value of storage for regulation of streamflow for the purpose of water quality control. The study area includes the Powder River Basin in Sheridan, Johnson, Natrona, and Campbell Counties in Wyoming and Powder and Custer Counties in Montana with special emphasis placed on Johnson County where the Kaycee Unit is located. The time period included in this study is from 1965 to 2065.

Since this study has been made in advance of the comprehensive study of water quality control for the Missouri River Basin, the findings presented are preliminary and subject to revision upon completion of such a comprehensive study.

Vector Control Problems associated with the Kaycee Project have been commented on in a separate report by the Disease Ecology Section, Communicable Disease Center, Greeley, Colorado, which has been submitted to the Bureau of Reclamation.

Acknowledgments

The assistance and cooperation of State and Federal agencies and individuals are gratefully acknowledged by the Federal Water Pollution Control Administration. Particular appreciation is expressed to the following for data and advice furnished by their staff members.

U. S. Bureau of Reclamation, Region 6
Regional Office, Billings, Montana
Sheridan Projects Office, Sheridan, Wyoming

Wyoming State Health Department
Cheyenne, Wyoming

Montana State Health Department
Helena, Montana

U. S. Geological Survey
Washington, D. C.

Fish and Wildlife Service
Wyoming and Montana

I. SUMMARY OF FINDINGS AND CONCLUSIONS

Summary of Findings

1. The Bureau of Reclamation, Region 6, Billings, Montana, is investigating the feasibility of expanding the irrigated acreage of the Kaycee Unit, an irrigation project, of the Powder Division located in the Powder River Basin of north central Wyoming. The proposed Hole-in-the-Wall Reservoir will impound approximately 40,000 acre feet on the Middle Fork of the Powder River.

2. This study encompasses the entire Powder River Basin which is located in Sheridan, Johnson, Natrona, and Campbell Counties in Wyoming and Powder River and Custer Counties in Montana. The Kaycee Unit is located almost entirely in Johnson County Wyoming. The economic evaluation in this study considered only Johnson County Wyoming and Powder River County Montana.

3. The population of the entire Powder River Basin is presently estimated at 10,000 of which 72% is rural. The major industry is agriculture where cattle raising predominates. Some oil production occurs in the southern portion of the basin.

4. The major use of water in the Basin is irrigation. The town of Kaycee does obtain its domestic water supply from infiltration galleries located on the Middle Fork of the Powder River. Kaycee has lagoon waste treatment which provides adequate treatment of the waste before it is discharged to the River.

5. Water quality in the Basin suffers from both geological influences and irrigation returns. Water from the mountain area is generally good (less than 500 mg/l total dissolved solids-TDS), but in the lower elevations the water quality deteriorates such that it would not be suitable for many purposes. The crops grown here are used to provide feed for the livestock industry (i.e., crops such as alfalfa, clover, barley, and oats which can be irrigated with waters of greater conductivities than 2250 micromhos/cm).

6. Groundwater is not a major source of water.

7. The available data indicates that the major contribution of natural pollution to the Powder River is from the Salt Creek and South Fork Powder River drainages. Further, it appears that the water quality of the Middle Fork Powder River deteriorates as it passes through a stretch of channel west of Kaycee.

Conclusions

1. Population projections indicate little change from the present and no increase is expected. Cattle raising will continue to dominate agricultural activities.

2. The Kaycee Unit will increase the amount of lands being irrigated. Data available at various points in the Kaycee Unit show a deterioration in water quality as the flows move downstream. Any depletion in present annual flows as a result of the project will further deteriorate water quality. Lack of data prohibits determination of when the worst condition (i.e., the month of the year) will occur.

3. Beneficial users of Powder River water below Moorhead (below the general Kaycee Unit area) are limited to a few hundred acres of irrigated land. The increased mineralization of the water as a result of the Kaycee Unit is not expected to significantly affect the irrigation downstream; therefore, no inclusion of storage in the Hole-in-the-Wall Reservoir for streamflow regulation for the purpose of water quality control has been made at this time.

II. PROJECT DESCRIPTION

The Kaycee Unit, as shown in Figure 1 at the end of this report, is located in north-central Wyoming in the headwaters of the Powder River near the town of Kaycee. This unit is a part of the Main Stem and Upper Tributaries Basin of the Powder Division in the Bureau of Reclamation's planning(1). The Kaycee Unit is to include all irrigable land which could be served from the Sahara Canal and the Powder River between the proposed Hole-in-the-Wall Reservoir and just north of Arvada, Wyoming(2), a distance of approximately 200 miles. At the Wyoming-Montana state line, the Bureau has proposed construction of the Moorhead Dam and Reservoir to control the flows of the Powder River as part of the Lower Powder River Basin development.

The proposed Kaycee Project contains approximately 14,200 acres of new lands and 6,800 acres of presently irrigated lands which have been irrigated by private systems for a great many years. About 4,700 acres of the new lands will be served by the Sahara Canal diverting water from the Powder River at the proposed Sahara Diversion Dam located about 6 miles east of Kaycee. The remaining acreage of new lands will be served by about 25 pumping plants providing water to areas ranging in size from 65 to 2,245 acres. These pumping plants would be spread out along the Powder River for about 165 miles below the Sahara Diversion Dam(2).

The proposed Hole-in-the-Wall Reservoir will provide a more dependable late summer supply of water in the main stem of the Powder River to the confluence with Clear Creek. Presently heavy late summer demand and erratic flows limit the amount of land that can be irrigated. Drainages from certain areas in the basin also contribute large concentrations of total dissolved solids which can be a problem to the irrigator.

The principal industry in the Powder River area is the raising of livestock. This industry requires feed crops such as alfalfa, oats (hay), barley (hay), and clover; crops which can be raised successfully on land irrigated by water from the Powder River and its tributaries. (In general, the above named crops can be grown on lands irrigated by waters with specific electrical conductances greater than 2250 micromhos/cm (umho/cm) if adequate drainage is provided).

III. STUDY AREA DESCRIPTION

For this study, the entire Powder River Basin was considered with particular attention to the Upper Basin (south of the Montana-Wyoming state line). The Powder River flows generally north-northeast from north central Wyoming to southeastern Montana and joins the Yellowstone River near Terry, Montana. The basin is long and narrow (300 miles x 80 miles) and lies between the Bighorn Mountains and the Belle Fourche drainage system. Seventy percent or 9,400 square miles of the basin is in Wyoming and thirty percent or 4,000 square miles is in Montana. While the Powder River Basin is 19% of the total Yellowstone River Basin it contributed only 3% of the total runoff during the drought of the 1930's(1), and an average of 5% during normal years. The Powder River has been characterized as the river "a mile wide, a foot deep, too thin to plow, and too thick to drink."

The topography(3) of the Powder River Basin is made up of three distinct and predominant types--mountains, foothills, and plains. If one were to traverse the basin, he would start in the rugged Bighorn Mountains where Cloud Peak is 13,165 feet in elevation with perpetual snow. These severely eroded granite ridges give way to an extensive plateau that is dissected by deep streamcut canyons. The foothills are a large hogback of plainward-dipping sedimentary rocks. The plains form a major portion of the basin and are semiarid. This part of the basin is made up of the rolling uplands, badlands, and the lowlands which contain the main streams.

Geologically(1) the structure of the Powder River Basin is a vast depression in the Great Plains province. Extensive sediments in the form of beds of sandstone, siltstone, claystone, and coal were deposited after the great mountain uplifts which surround the structural basin. Erosion is gradually lowering the entire area as the streams carry away the eroded materials. The greater portion of the exposed sedimentary rocks in the Powder River Basin includes the Lance, Fort Union, and Wasatch formations.

Because of the continental character of the climate in the plains there is a wide variation in temperature and the average frost-free period varies from 121 days to 141 days depending on location in the basin. There is an abundance of sunshine but winters can be severe. The weather station at Sheridan recorded a mean annual temperature of 43.9°F with a range of -41°F to 106°F. Average annual precipitation amounts to 15.4 inches of which 8.2 inches occurs between May and September. Snowfall is 55 inches. A weather station located at Kaycee since 1941 indicates for a 15-year period that the average annual precipitation was 12.11 inches with a range from 9.0 to 17.8 inches.

The largest town in the basin is Buffalo with a population of approximately 2,900. The larger population centers are located just outside the basin at Sheridan and Gillette.

Industry is limited to agricultural activities with some oil production in the southern portion of the basin.

IV. WATER RESOURCES OF THE STUDY AREA

Quantity of Water Available

In the Powder River Basin, streamflows supplied from the higher elevations are characterized by the high spring runoff from snowmelt and the rather constant baseflow thereafter. Those streams originating in the plains area depend on occasional rains of moderate to heavy intensity and are dry much of the year since there is little groundwater recharge. Because of irrigation demands, flows in the Powder River are erratic during the late summer months and at times there is no flow in the Powder River between Sussex and the confluence with Clear Creek. Appendix A provides selected streamflow records available in the basin giving the length of record, maximum, minimum, and the average flow. Only the Middle Fork and North Fork of the Powder River have minimum flows greater than 0. Appendix B compares the monthly and annual streamflows at select points in the Powder River Basin.

The U. S. Geological Survey in Water Supply Paper 1360-E(12) has evaluated groundwater sources from Arvada, Wyoming, to Kaycee. This report observed that where there was groundwater potential in this area it was generally highly mineralized and, therefore, was not considered as an alternative supply for irrigation. Presently groundwater is used for municipal supplies elsewhere in the basin. Limited investigations by the Bureau of Reclamation in Crazy Woman Basin show no probable underground sources of water sufficient for any appreciable amount of irrigation(1). Along the Powder River, however, many wells are in use for stock watering(7) and Gillette, Wyoming, just to the east of the basin, obtains municipal supplies from wells.

As for obtaining additional water via transbasin diversion, the Bureau of Reclamation has not found any opportunities that were feasible(1).

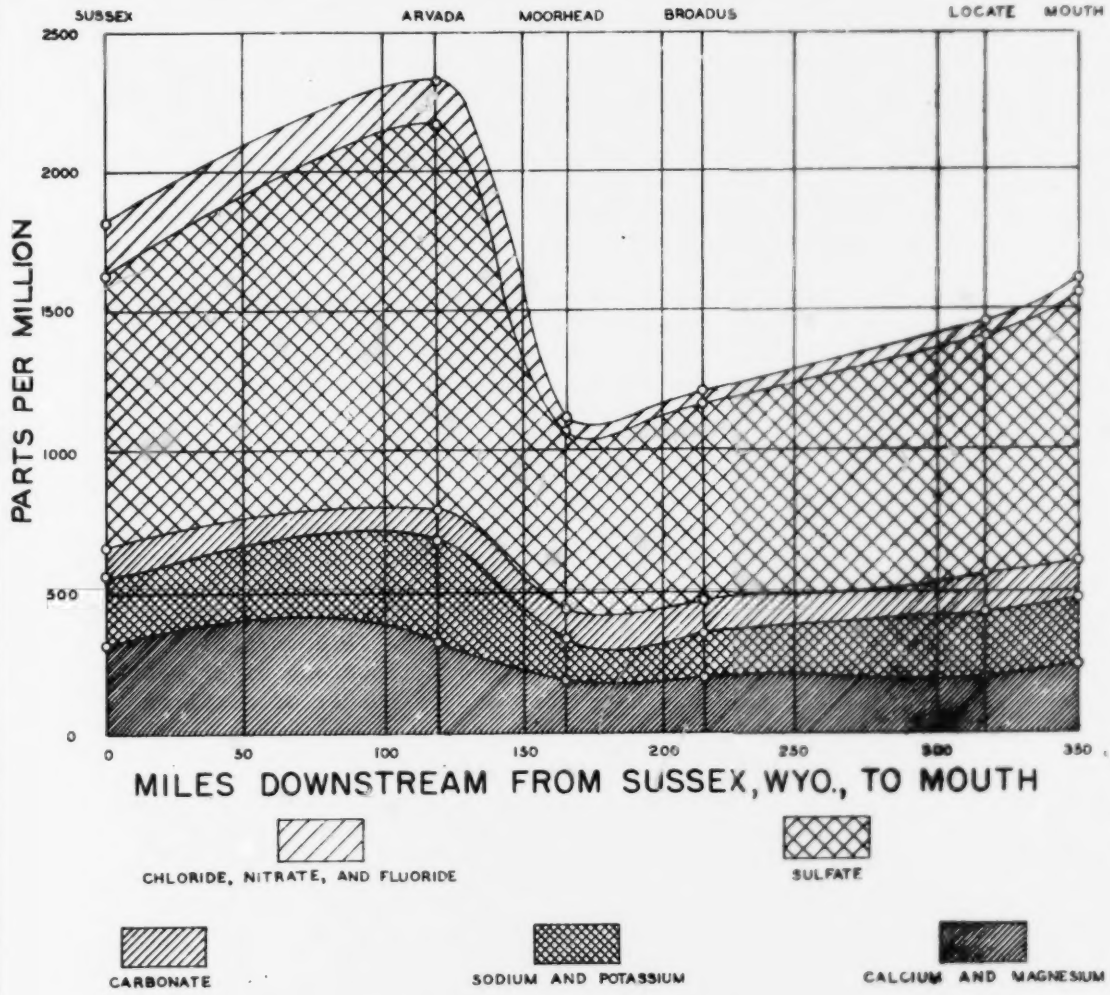
Quality of Water Available

The quality of water in the Powder River Basin is largely affected by the varied geologic formation of the area through which it flows with resulting wide fluctuation in both the composition and salinity of the water. A study by the U. S. Geological Survey(3) reveals, for example, that Clear Creek, which originates in the pre-Cambrian granites in the Bighorn Mountains, is a calcium carbonate water of low mineral content. In contrast, the Little Powder River which has its source in the upland country of Tertiary sandstone and shales results in a water of high mineral content and hardness. This water contains more sulfate than

bicarbonate. The drainage area of the Middle Fork of the Powder River is underlain by limestone which has tended to produce a water of moderate mineral content, made up largely of carbonates. Near Kaycee the Middle Fork passes through an area underlain by gypsum beds, gypsiferous shales, and siltstones where mineral content increases considerably and sulfate becomes the major constituent.

Appendix C illustrates typical water quality for various locations in the Powder River Basin. Figure 2 is reproduced from USGS Circular 170(3) and shows the composition of the main stem from Sussex to the confluence with the Yellowstone River. Figure 3 shows TDS values found by USGS in their survey of September 10-14, 1949.

Observations(4) made in the early 50's near Broadus, Montana, state that very little use of the Powder River is made for any purpose since the quality is poor and the banks are unstable. Cattle do not graze along the bank because of quicksand. The high turbidity in the lower reaches prohibits fishing or recreation. As the river passes through the badlands, it gathers considerable silt resulting in many sand bars and mud flats. The channel is relatively shallow, wide, and unstable. Paradoxically by the time the flow reaches the Yellowstone River west of Terry, much of the silt load has been lost as the result of settling actions(5).



NOTE: This figure is taken from USGS Cir. 170 P55

WATER QUALITY CONTROL STUDY
POWDER RIVER BASIN

COMPOSITION OF WATER IN POWDER RIVER AT LOW STAGE SEPT. 11 TO 14, 1949

US DEPARTMENT OF HEALTH, EDUCATION & WELFARE
Public Health Service
REGION XIII DENVER, COLORADO

FIGURE 2

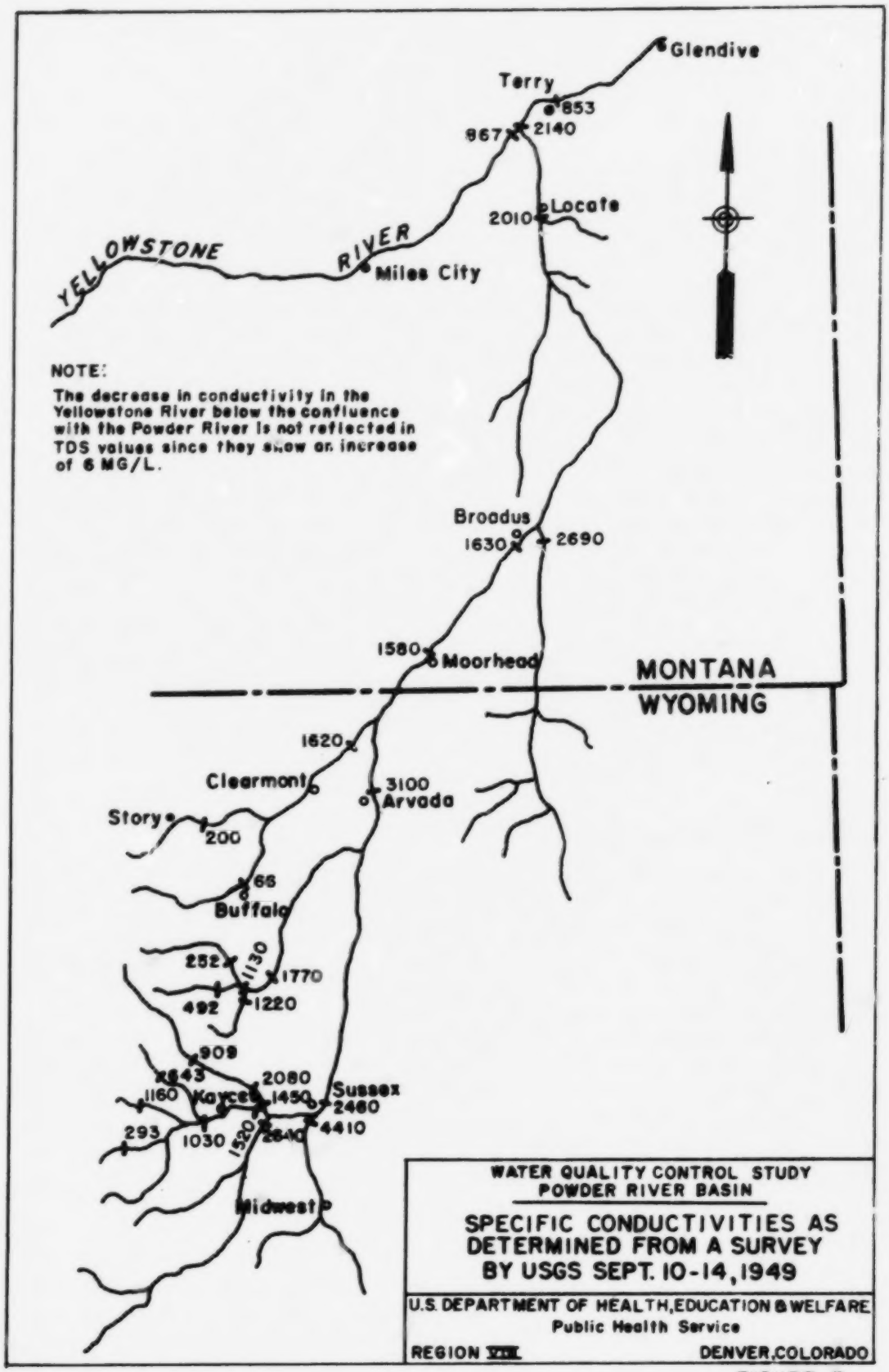

Glendive
Terry
853
967
2140
Locate
2010
YELLOWSTONE
RIVER
Miles City
NOTE:
The decrease in conductivity in the Yellowstone River below the confluence with the Powder River is not reflected in TDS values since they show an increase of 6 MG/L.
Broadus
1630
2690
1580
Moorhead
MONTANA
WYOMING
1620
Clearmont
3100
Arvada
Story
200
66
Buffalo
252
1130
1770
492
1220
909
643
2080
1160
Kaycee
1450
Sussex
2460
293
1030
1520
2640
4410
Midwest
WATER QUALITY CONTROL STUDY
POWDER RIVER BASIN
SPECIFIC CONDUCTIVITIES AS DETERMINED FROM A SURVEY BY USGS SEPT. 10-14, 1949
U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
Public Health Service
REGION VIII
DENVER, COLORADO

FIGURE 3

V. THE ECONOMY

This river basin is on the high semiarid plains of southeastern Montana and northeastern Wyoming. It is open, rolling, bleak country, an endless succession of bluffs, breaks and hummocks. It is a vast grassland that was a favorite range of enormous herds of buffalo until fashion decreed the slaughter of the buffalo in the 1870's. In the 1880's it was an open range stocked with cattle driven up from the south by men who laid tenuous claim to portions of the public domain to graze their herds for a season, a year, or longer. In the 1890's the herds of cattle were joined by bands of sheep. At the turn of the century the days of the open range were ended by homesteaders who broke the prairie sod to raise crops. This country, however, with its dry, hot summers and long, cold winters has been inhospitable to the farmer who has yielded again to the cattleman. Today the economic activity in the Powder River Basin is almost exclusively devoted to the range livestock industry. Perhaps the most eloquent testimony to the general character of the area is the fact that so few people choose to live there. The population density is only about one person per square mile, compared to 3.4 for the State of Wyoming, 4.6 for the State of Montana, and 50.5 for the United States.

The area chosen for analysis in this economic survey consists of Johnson County, Wyoming, and Powder River County, Montana. While these two counties do not encompass the entire Powder River Basin (Kaycee Project lands are almost entirely within the boundaries of Johnson County), they have been selected as most typical of the basin and the trends and conditions seen here will characterize the entire basin.

Present and Historic Economic Activities

The predominance of agriculture as a source of livelihood for the people of the area is shown in the amount of their resources devoted to it. In 1960, nearly 62 percent of the employment in Powder River County and 28 percent in Johnson County was in agriculture, a significantly higher amount than in the State of Montana (18 percent), the State of Wyoming (13 percent), or the United States (6 percent). There are nearly four million acres of land in farms. Only one percent of this acreage is in small grains such as wheat, oats, and barley. Another two percent is in hay crops. About 49,000 acres are irrigated. The balance of the area in farms is range land for cattle grazing. Four hundred and ninety-five of the 628 farms in the area in 1960 were caregorized as livestock farms or ranches, the average size of which was over six thousand acres. The value of all farm products sold in the two counties in 1959 was $11,480,754. All crops sold accounted for only $1,067,630 of this

amount while livestock and livestock products sold amounted to $10,413,124. There were more than 110,000 cattle and 225,000 sheep on the ranges in 1959. Winter wheat is the most important cash crop grown with 21,000 acres harvested, most of which was in the northern portion of the basin. This is a marginal wheat growing area, and the future use of land for this activity is questionable.

Although the area is underlain by extensive deposits of coal, much of it in beds 10 to 140 feet thick, no mining of it takes place. Interest in future use has been demonstrated by a major aluminum company which has purchased property around Lake DeSmet north of Buffalo with the apparent intention of converting the available coal and water resource into electricity, a major input in aluminum production, at sometime in the future. A portion of the Salt Creek oil field now the second largest producer in Wyoming lies in the southern part of this Basin at Midwest and just outside the Basin at Casper. There are eight producing oil fields in Johnson County and 6,264,000 barrels of oil were produced in the County in 1962. A new well northeast of Kaycee which began producing 800 barrels daily in March 1963, was described by oil company officials as the "most significant" oil discovery in the Rocky Mountain region in the last decade. Nevertheless, the major impact of this activity is outside our study area. Bentonite deposits in the vicinity of Kaycee have potential commercial value. Total value of all mineral production in Johnson County in 1962 was over $18 million. The amount received as payroll by workers in the County was less than five percent of this amount.

The number of people engaged in manufacturing was only 82 in 1960, less than three percent of employment. There were 12 manufacturing establishments, only one of which hired more than twenty people. Value added by manufacturing was just over a quarter of a million dollars in 1958. Lumber and wood product firms predominate.

The area is served by three U. S. Highways, two of which are part of the Interstate Highway system, connecting Billings and Sheridan with Rapid City, South Dakota, to the east and Casper, Cheyenne, and Denver to the south. There is no all-weather highway running the length of the basin. A branch line of the Chicago, Burlington, and Quincy Railroad connecting Billings, Montana, with Omaha, Nebraska, crosses the basin at about its mid-point in a southeast-northwesterly direction. The Chicago and Northwestern Railroad skirts the southern edge of the basin while the Northern Pacific and the Chicago, Milwaukee, St. Paul, and Pacific Railroad pass it to the north.

Income is a rough measure of the economic welfare of people. The median family income in this area is only about eighty-nine percent that of the surrounding states. In Powder River County this is a decreased percentage from a decade ago, in Johnson County an increasing percentage.

Median Family Income-1960

Montana	$5,403	
Powder River County		$4,797
Wyoming	$5,877	
Johnson County		$5,250
United States	$5,666	

Population

Population of the area has generally declined over the past thirty years as seen in the table below, although population in the southern (Wyoming) portion increased between 1950-60. The populations of the two counties studied are comprising a smaller and smaller portion of the population of their respective states.

Area	1930	1940	1950	1960	% Chg. for 1930-40	% Chg. for 1940-50	% Chg. for 1950-60
Study Area	8,725	8,139	7,400	7,960	-6.7	-9.1	+7.6
Johnson Co, Wyo	4,816	4,980	4,707	5,475	+ .03	-5.5	+16.3
Buffalo	1,749	2,302	2,674	2,907	+31.6	+16.2	+ 8.7
Kaycee	161	210	211	284	+30.4	+ 0.4	+34.6
Wyoming	225,565	250,742	290,529	330,066	+11.2	+15.9	+13.6
Powder River Co	3,909	3,159	2,693	2,485	-19.2	-14.8	- 7.7
Broadus	-	-	517	628	-	-	-
Montana	537,606	559,456	591,024	674,767	+ 4.2	+ 5.6	+14.2
United States					+ 7.3	+14.5	+18.5

The two "population centers", Buffalo, Wyoming, and Broadus, Montana, are growing but not rapidly. Buffalo, in fact, had a smaller share of Johnson County's total population in 1960 than 1950. Future population growth will likely be moderate and will be mostly in the southern part of the Basin while the number of people in the northern part will continue to decline somewhat. There will be perhaps 9,500 people in the study area by 1980, 11,000 by the year 2000, and 20,000 by 2065.

Future

This area by and large seems to be stabilizing as a cattle grazing economy (the southernmost portion excepted.) The local market is too small to encourage much development in services or manufacturing and larger markets are too far distant. Future growth will be based mostly on development of the area's mineral resources. Continued production of petroleum will be the source of much future development, but this industry is not a large employer, except at a refining center which is not likely to develop in the study area. Oil production is confined almost entirely to the southern portion of the basin, which largely accounts for the divergent trends in population and income between the northern and southern portion of the basin. The coal resources are another potential source of future development, and some industrial interest has been shown. This remains a nebulous prospect, however. Growth of the tourist industry, centered around Buffalo, Wyoming, which is on the new interstate highway, is a much more likely possibility for the immediate future. It is believed that water use in the area will remain largely agricultural and it is unlikely that municipal or industrial activity will become a significant hazard to existing water quality.

VI. WATER QUALITY CONTROL

The Powder River Basin is not heavily populated and does not suffer from municipal or industrial pollution. Nature has not endowed this area generously, and little economic growth has been forecast for the future. The plains area is semiarid and therefore sparse of vegetation. This, coupled with man's activities and the influence of the geological factors, has a significant impact on water quality.

Municipal, Industrial, and Agricultural Pollution

Waste discharges along the Powder River from municipal or industrial activities are limited to the towns of Kaycee and Broadus where lagoons are in operation. With the flows available at these specific points in the river no problem is contemplated especially since discharge from the lagoons will be extremely low during high evaporation months. Discharges from the town of Buffalo and the Old Soldiers Home to Clear Creek and the industrial activity at Midwest to Salt Creek would not be benefited because of geographical location by streamflow regulation from the proposed Hole-in-the-Wall Reservoir and have not been investigated.

Appendix D provides data on the remaining towns in the basin. There are no municipal or industrial waste sources present or anticipated that cannot be treated sufficiently with present known methods to avoid pollution problems in the basin.

Agricultural pollution* is another matter entirely, since in the Powder River geologic factors degrade the water considerably. Use of water for irrigation intensifies this mineral pollution especially during periods of low streamflow. Lands irrigated from the Sahara Canal and upstream will benefit to some extent from the mixing effect of the Hole-in-the-Wall Reservoir with water of better quality being released during July, August, and September. Much of this benefit will, unfortunately, be negated by the pickup of minerals in the river channel near Kaycee(3). Control of agricultural pollution has not benefited from a suitable method of treatment except improved farm management. Another remedy is the complete removal of land from irrigation but in an agricultural economy this has not been found practical to date.

*Water is said to be polluted when its character is changed by the addition of materials, or in any other manner, in such a way that the usefulness of the water is reduced(10).

Water Quality Criteria

Dissolved oxygen and dissolved minerals were the major water quality criteria considered in this study. Adequate concentrations of dissolved oxygen are necessary for maintaining fish life and to prevent the formation of odoriferous gasses, which generally occurs under anaerobic or near anaerobic conditions. A minimum dissolved oxygen concentration of 4 mg/l should be adequate for maintaining the warm water fish which are found in sections of the Powder River between the Hole-in-the-Wall Reservoir and the Yellowstone River. In addition, this dissolved oxygen concentration will prevent the formation of odoriferous gasses under conditions expected in the Powder River.

The suitability of water for use in irrigation is partially dependent on its concentrations of dissolved minerals. Individual mineral constituents such as chloride and boron can have toxic effects on plants when present in sufficient concentrations. The relative concentration of sodium to that of calcium and magnesium (sodium adsorption ratio) is important when the water is used to irrigate clayey soils. Excessive concentrations of total dissolved solids (TDS) affects the ability of plants to utilize the water. The critical concentrations of the various mineral constituents depend on such factors as the type of plant being irrigated, the type of soil, the type of irrigation used, the amount of water applied, and the method of soil preparation. Because of these many factors, no rigid limits of salinity can be set for irrigation waters. Water having TDS concentrations up to 2150 mg/l is suitable for most plants except sensitive ones(6). Generally, TDS concentration of 3150 mg/l is near the maximum for the safe watering of any plant, and in such instances drainage must be excellent and each watering should permit leaching from the root zone.(6)

Flow Regulation

In the main stem of the Powder River the degradable wastes present are not expected to lower DO levels significantly nor do economic projections indicate problems in the future. The Bureau of Sport Fisheries and Wildlife has not specified flow requirements below the Hole-in-the-Wall Reservoir for the purpose of providing a fishery. They will submit a report as soon as their study of this project is complete(9).

Mineral pollution is present as the result of natural conditions and irrigation. This pollution is greatest in the plains area but for the particular economy in the basin the degree of this pollution has been tolerable in the past. Future mineral concentrations of the water

will be intensified with the additional land brought under irrigation. Present or projected water uses in the basin do not require water of significantly better quality than that presently available or anticipated.

Based on the water quality data available for the Middle Fork of the Powder River at the Hole-in-the-Wall Reservoir site, the flow weighted mean annual TDS is about 560 mg/liter with a range from 230-930 mg/l; the better quality flows occurring in late April, May, June, and early July. Construction of the Hole-in-the-Wall Reservoir will increase the mean annual TDS concentration to 580 mg/liter, assuming that the inflows are completely mixed with the reservoir contents and allowing for evaporation. The reservoir will tend to smooth out the fluctuations in water quality; releases for May through September should average about 550 mg/l TDS; those for October through April should average about 600 mg/l TDS.

Estimates were also made of the effects of the Kaycee Unit on downstream water quality in the Powder River at Arvada, Wyoming; at Moorhead and Locate, Montana; in the Yellowstone River just below the mouth of the Powder River; and in the Yellowstone River at Sidney, Montana, about 110 miles downstream of the confluence of the Powder River. No water quality data was available on the Yellowstone River just below the mouth of the Powder River, so it was necessary to take the data of a station at Miles City, Montana, (about 40 miles upstream). By knowing the salt load contributed by the Powder River, it was possible to get an estimate of its effect on water quality in the Yellowstone River just below the mouth of the Powder.

The flow weighted mean annual TDS concentrations and mean annual flows under existing conditions were calculated from records available at the above locations. To calculate the mean annual flow with project conditions the mean annual flows for existing conditions were depleted by 28,500 acre-feet; this figure representing the depletion due to evapotranspiration losses from the newly irrigated lands. Using a 1:1 salt balance the mean annual TDS concentrations that would occur with project conditions were calculated and are shown in Appendix E.

Average monthly TDS concentrations after the project are desirable; however, since data on the quality of irrigation waters (i.e., the salt load diverted to the fields each month of the irrigation season), the quality of irrigation return flows (salt-load returned to river each month), and the monthly depletions in streamflow are not available or predictable at this time, an analysis of this sort is not possible.

If the Kaycee Unit is constructed and operated as presently planned, calculations on an annual basis indicate that the flow weighted mean annual TDS concentration at Locate would increase approximately 10 percent,

or from 1120 mg/l to 1230 mg/l. The increase in TDS concentration in the Yellowstone River at the confluence with the Powder River would be about 2 percent (397 mg/l to 405 mg/l), while downstream near Sidney the increase would be less than 0.5 percent (Appendix E).

There is a small amount of acreage (estimated at less than 1000 acres) below the Kaycee Unit which is presently being irrigated from the Powder River. Appendix E shows the percent increase in annual TDS values at Arvada, Moorhead, and Locate due to the depletion of present flows. To determine what effects this increase would have on downstream users, namely irrigators, consideration was given to the increase in leaching requirements(15). On the basis of the annual TDS values (present and future) at the above locations and assuming that the electrical conductivity of the drainage water had a maximum value of 8 millimhos, the leaching requirements at Arvada would be increased by 23 percent, at Moorhead by 13 percent, and at Locate by 11 percent. These increases in the leaching requirement should present no problem since the total leaching requirement is still less than the 30-35 percent deep percolation losses (i.e., 30-35% of the water applied) that normally occur with conventional surface irrigation methods. However, it must be remembered that these increases are also based on annual averages. During periods of low flow TDS values in the river may be much higher than the annual average. The proposed Moorhead Reservoir as part of the Lower Powder River Development would supply all land below the reservoir with a full supply of water. This reservoir would probably help smooth out the fluctuations in TDS concentrations similar to that which would be provided by the Hole-in-the-Wall Reservoir.

Other than the increased leaching requirements which may be necessary during periods of low flow, there will be no apparent damages to downstream users. Therefore, no need is foreseen at this time for the inclusion of storage in the Hole-in-the-Wall Reservoir for the purpose of streamflow regulation for water quality control.

Possible improvement in water quality could be obtained by controlling the flows of Salt Creek and the South Fork of the Powder River. Further study would be necessary to define the benefits attributable to the farmers along the Powder River for an improvement in water quality from this control. This would be expected to be small with the present and projected economy for the basin, but the current comprehensive study under way for the Missouri River Basin may provide other conclusions.

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APPENDIX A

Selected Streamflow Records - USGS

Station	Period of Record	flow in cfs Max.	Min.	Avg.
Wyoming				
Middle Fork Powder River above Kaycee, Wyoming	April 1949-Sept. 1964	1,610	12	64.6
North Fork Powder River near Mayoworth, Wyoming	Oct. 1940-Sept. 1964	1,270	5.6	32.0
Powder River near Kaycee, Wyoming	Oct. 1940-Sept. 1964	5,230	0	125
South Fork Powder River near Kaycee, Wyoming	May 1950-Sept. 1964	35,500	0	37.1
Crazy Woman Creek near Arvada, Wyoming	Oct. 1939-Dec 1943 Jan. 1950-Sept. 1964	2,900	0	40.0
Powder River at Arvada, Wyoming	May 1919-Sept. 1964	100,000	0	267
Clear Creek near Arvada, Wyoming	Sept. 1939-Sept. 1964	9,600	0	177
Montana				
Yellowstone River at Miles City, Montana	Aug. 1928-Sept. 1964	96,300	996	10,840
Powder River at Moorhead, Montana	May 1929-Sept. 1964	23,000	0	441
Little Powder River near Broadus, Montana	May 1947-Sept. 1953 Mar. 1957-Sept. 1964	2,340	0	29.6
Powder River near Locate, Montana	March 1938-Sept. 1964	31,000	0	595
Yellowstone River near Sidney, Montana	Oct. 1933-Sept. 1964	159,000	470	12,800

APPENDIX B

AVERAGE MONTHLY FLOWS - POWDER RIVER BASIN*

	Description	Units	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Total
1.	Middle Fork Powder River above Kaycee (Hole-in-the-Wall Damsite) Streamflow for April 1949-September 1963	AF*	2.5	2.6	2.6	2.4	2.5	2.8	4.7	12.6	6.2	2.6	1.8	1.9	45.0
		CFS	40.5	43.7	42.1	38.9	44.8	45.4	78.9	204.12	104.2	42.1	29.2	31.9	
2.	Powder River near Kaycee October 1950-September 1963	AF	3.1	5.3	5.3	5.0	5.5	6.7	8.9	18.9	9.2	1.8	0.3	1.0	17.1
		CFS	50.2	89.0	85.9	81.0	98.5	108.5	149.5	306.2	154.6	29.2	4.9	16.8	
3.	South Fork Powder River near Kaycee May 1950-September 1963	AF	1.8	1.0	1.1	.8	1.9	3.9	2.7	6.4	2.7	2.4	0.6	1.6	26.7
		CFS	29.2	16.8	17.8	12.9	34.0	63.2	45.4	103.7	45.4	38.9	9.7	26.9	
	Powder River Accretions between South Fork and Sussex (Salt Creek+Drainage) October 1951-September 1963	AF	.9	.6	.4	.7	1.3	2.8	2.6	6.5	4.4	1.4	.9	.7	23.0
		CFS	14.6	10.1	6.5	11.3	23.3	45.4	43.7	105.3	73.9	22.7	14.6	11.8	
4.	Powder River at Sussex February 1950-September 1963	AF	5.5	6.8	6.7	6.4	8.5	13.1	14.3	32.0	16.0	5.5	1.8	3.2	118.8
		CFS	89.1	114.2	108.5	103.7	152.2	212.2	240.2	518.4	268.8	89.1	29.2	53.8	
5.	Powder River at Arvada October 1950-September 1963	AF	4.7	4.7	4.4	3.6	7.4	20.1	16.3	35.7	36.8	11.6	5.0	3.3	153.7
		CFS	76.1	78.9	71.3	58.3	132.5	325.6	273.8	578.3	618.2	187.9	81.0	55.4	
6.	Powder River near Moorhead October 1951-September 1963	AF	8.0	10.0	9.5	7.7	12.9	30.0	25.6	48.4	68.4	21.3	8.4	5.6	255.9
		CFS	129.6	168.0	153.9	124.7	230.9	486.0	430.1	784.1	1149.1	345.1	136.1	94.1	
7.	Little Powder River near Mouth		(incomplete data for period of record considered)												23.4
8.	Powder River at Locate October 1951-September 1963	AF	6.9	7.1	7.9	5.7	18.1	59.0	36.9	48.9	80.3	29.8	11.7	7.3	319.7
		CFS	111.8	119.3	127.9	92.3	323.9	955.8	619.9	792.2	1349.0	482.8	189.5	122.6	
9.	Yellowstone River at Miles City Streamflow for October 1951-September 1963	AF	458.6	421.1	354.4	298.3	332.0	460.9	444.8	995.3	2009.1	1049.8	451.6	394.4	7670.6
		CFS	7430.9	7074.5	5741.3	4832.5	5942.8	7466.6	7472.6	16123.9	33752.9	17006.8	7315.9	6625.9	
10.	Yellowstone River near Sidney Streamflow for October 1951-September 1963	AF	643.3	418.4	342.2	299.9	362.7	590.4	565.1	963.5	2081.0	1077.2	416.6	357.2	7918.0
		CFS	10421.5	7029.1	5543.6	4858.4	6492.3	9564.5	9493.7	15608.7	34960.8	17450.6	6748.9	6000.9	

* AF in 1000 Units

Note -- Figure 1 shows location of these points as (1) etc. These data cover generally the period from 1949 to September 1963 only.

*Source: These data were provided by the Bureau of Reclamation except for items 6 through 10 which were obtained from USGS publications and are not adjusted.

APPENDIX C

Chemical Quality of Surface Water - Powder River Basin*

		Discharge cfs	pH	EC x 10^6 Micromhos	Silica SiO_2	Iron Fe	Calcium Ca	Magnes Mg	Sodium Na	Potas-sium K	Bicarb. HCO_3	Sulfate SO_4	Chloride Cl	Fluoride F	Nitrate NO_3	Boron B	Hardness $CaCO_3$	% Sodium
1) Middle Fork Powder River above Kaycee Sept 1949 June 1952-Sept 1953	Max	270	8.1	3120	40	.1	590	149	96	9.5	440	1890	18	1.0	3.4	.21	2080	22
	Min	19	6.8	337	10	0	47	9	8	1.1	102	81	3	0.1	.3	.05	154	9
	Wt Avg		-	808	-	-	110	33	24	2.3	177	296	10	-	-	-	410	-
2) Middle Fork Powder River near Kaycee May 1946-Sept 1953	Max	720	8.4	2310	39	0.1	463	65	206		302	1310	144	0.8	5.3	0.3	1420	50
	Min	0.3	7.1	502	5.8	0	54	10	18		138	123	7.5	0.1	0.1	-	201	8
	Wt Avg		-	853	-	-	84	28	74		183	272	29	-	-	-	325	-
3) South Fork Powder River near Kaycee Sept 1949-Sept 1953	Max	504	8.4	5260	34	0.16	416	140	820		500	2660	643	3.2	56	0.54	1620	54
	Min	6.3	6.8	1880	10	0	204	44	164		89	770	27	0.8	0	0.18	674	27
	Wt Avg		-	2945	-	-	290	69	350		254	1390	99	-	-	-	1011	-
4) Powder River at Sussex Mar 1950-July 1953	Max	1460	8.1	4530	23	.10	433	126	602		305	1640	327	1.1	10.0	0.34	1600	51
	Min	9.5	6.9	790	8.6	.02	75	24	48		150	239	33	0.4	0.7	0	286	10
	Wt Avg		-	2145	-	-	201	60	319		206	675	79	-	-	-	751	-
5) Powder River at Arvada May 1946-Aug 1953	Max	4740	8.5	3080	25	0.5	341	156	367		416	1330	127	.8	7.8	.35	1170	48
	Min	1.5	6.6	704	7.2	0.02	94	24	37		124	203	21	.3	.8	.05	333	14
	Wt Avg		-	1729	-	-	191	51	180		194	716	39	-	-	-	684	-
6) Salt Creek near Sussex Sept. 1949 May-June 1952	Max	-	8.3	5610	16	0.10	310	-	967		323	2800	302	1.0	2.6	0.66	1340	61
	Min	-	7.1	2660	5.6	.04	151	-	419		179	1180	86	0.7	0.0	0.22	599	56
7) Crazy Woman Creek near Arvada Dec 1949-Sept 1950 (5)	Max	137	7.9	2290	28	.2	224	120	171		330	1080	19	.4	3.0	.4	1050	30
	Min	12	7.4	842	7	.02	76	32	63		148	313	5	.1	.8	.05	321	25
8) Clear Creek near Arvada Dec 1949-Sept 1950 (5)	Max	417	8.0	1820	14	.04	157	88	171		308	845	7	.4	6.3	.3	754	33
	Min	3.9	7.3	494	6.4	.02	46	19	29		119	14	1	.1	1.8	.1	193	24
9) Powder River near Locate, Montana Nov 1945- Aug 1948-Sept 1950 Oct 1951-Sept 1959	Max	11,100	8.0	3700	38	0.2	322	145	512		685	1710	116	0.6	7.0	0.3	1400	53
	Min	0.1	6.9	640	8.4	0.02	56	18	55		130	265	7	0.2	0.6	0	206	31
	Wt Avg		-	1160	12	0.04	99	33	118		188	446	23	0.47	3.2	.15	402	38
10) Powder River at Moorhead Oct 1951-Sept 1957	Max	462		1520			166	51	118		206	643	35		3.6	0.15	624	33
	Min	306		1330			133	44	105		182	531	33		2.8	0.12	513	28
	Wt Avg	363		1415			153	47	113		199	580	34		3.1	0.14	572	30
11) Yellowstone River at Sidney Oct 1951-Sept 1958	Max	13,370		722			55	19	66		177	215	8.9		2.7	0.12	233	38
	Min	8,986		561			48	16	47		155	148	7.5		2.0	0.11	186	34
	Wt Avg			638			52	18	55		168	186	8.2		2.4	0.12	211	36

* "Quality of Surface Waters of the U. S.", USGS 1952-59.

Appendix D

Wastes and Waste Loads - Municipal and Industrial*

Location and Name of Municipality or Industry	River Miles Above Mouth	Sewered Population	P. E. Waste Before Treatment	Nature of Waste	Treatment Provided	P E Discharge to Water Course
Middle Fork Powder River	381					
Kaycee, Wyoming	381-7	270E	270E	Municipal	Lagoon	30E
Salt River	353					
Edgerton, Wyoming		None	-	-	-	-
Midwest, Wyoming	353-31	1,000	1,000	Municipal	Lagoon	150E
Clear Creek	210					
Buffalo, Wyoming	210-80	2,000	3,000E	Municipal	Lagoon	300E
Old Soldiers Home		60	60E	Domestic	Secondary	15E
Story, Wyoming		None	-	-	-	-
Clearmont, Wyoming		None	-	-	-	-
Powder River	0					
Linch, Wyoming		None	-	-	-	-
Sussex, Wyoming		None	-	-	-	-
Arvada, Wyoming		None	-	-	-	-
Moorhead, Montana		None	-	-	-	-
Broadus, Montana	138	600	600E	Municipal	None	600E
Powderville, Montana		None	-	-	-	-
Mizpah, Montana		None	-	-	-	-
Locate, Montana		None	-	-	-	-
Little Powder River	129					

* U. S. Department of Health, Education, and Welfare, Public Health Service, 1962 Inventory of Municipal Waste Facilities, Washington, D. C., 1963.

APPENDIX E

Estimated Effects on Water Quality After Project

Location	Historic Conditions			With Project Conditions						
	Flows	Concentrations		Depletions	Flows	Concentrations		Total Tons		% Increase in TDS Concentration Over Historic
	1000 Ac-Ft Year	TDS mg/l	TDS Tons/AF	1000 AF/YR	1000 AF/YR	TDS mg/l	TDS Tons/AF	Annual	Daily	
1. Hole-in-the-Wall Reservoir	45.0	560	0.76	1.6 4/	43.4	580	0.79	34,200	94	4
2. Arvada, Wyoming	154.0	1310	1.78	28.5 5/	125.5	1610	2.18	274,100	751	23
3. Moorhead, Montana	256.0	1110	1.52	28.5	227.5	1250	1.70	386,560	1,060	13
4. Locate, Montana	320.0	1120	1.52	28.5	291.5	1230	1.67	486,400	1,332	10
5. Miles City, Montana	7671	366	0.50	-	7671	366	0.50	3,835,000	10,508	0.0
6. Just below mouth of Powder River	7991 3/	397	0.54	28.5	7963	405	0.55	4,321,000	11,840	2.0
7. Sidney, Montana	7918	427	0.58	28.5	7889.5	429	0.583	4,592,000	12,580	>0.5

1/ Location 1 is on the Middle Fork of the Powder River; 2, 3, and 4 are on the Powder River; locations 5, 6, and 7 are on the Yellowstone River. Miles City is about 40 miles above the mouth of the Powder River; Sidney is 110 miles below.

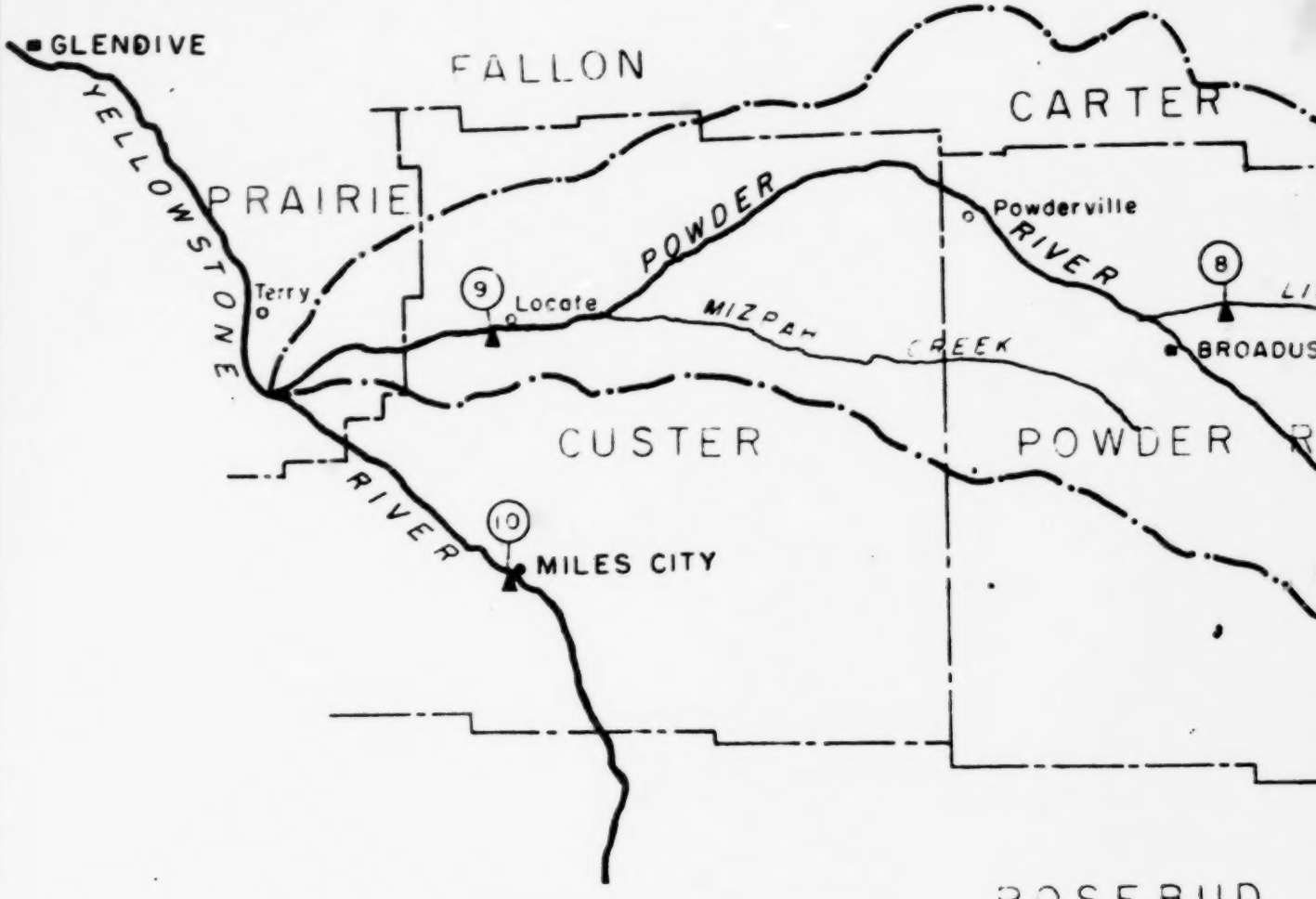
2/ Historic records from USGS data: Flows - from October 1951 to September 1963; water quality data - whatever was available.

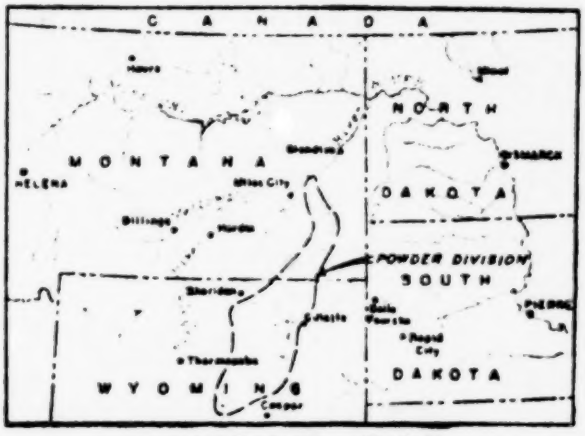
3/ An approximation of the flows in the Yellowstone just below the mouth of the Powder River since no records are available at that point.

4/ Depletion of 1,600 ac-ft/year represents reservoir evaporation. No allowance made for depletions due to upstream development on the Middle Fork of the Powder River.

5/ 28,500 ac-ft represents the irrigation demands on new land in the Kaycee Unit.

Sidney, Montana is near the mouth of the Yellowstone River and near the North Dakota state line.



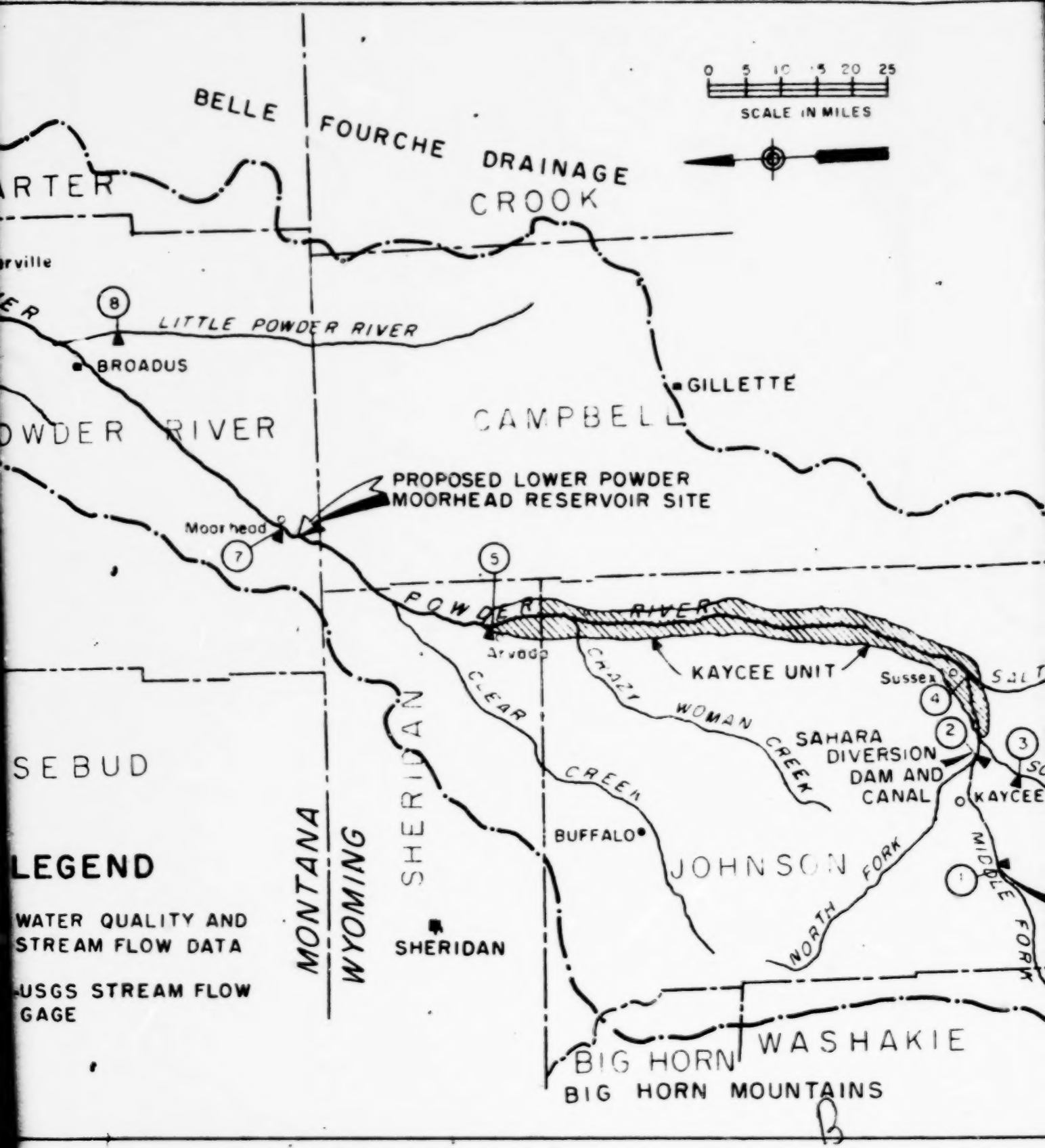


LOCATION MAP

LEGEND

(1) WATER QUALITY
STREAM FLOW

▲ USGS STREAM
GAGE


0 5 10 15 20 25
SCALE IN MILES
BELLE FOURCHE DRAINAGE
CROOK
LITTLE POWDER RIVER
BROADUS
GILLETTE
CAMPBELL
PROPOSED LOWER POWDER
MOORHEAD RESERVOIR SITE
Moorhead
POWDER RIVER
Arvada
KAYCEE UNIT
Sussex
SALT
CLEAR CREEK
CRAZY WOMAN CREEK
SAHARA
DIVERSION
DAM AND
CANAL
KAYCEE
BUFFALO
JOHNSON
NORTH FORK
MIDDLE FORK
MONTANA
WYOMING
SHERIDAN
SHERIDAN
BIG HORN
WASHAKIE
BIG HORN MOUNTAINS
LEGEND
WATER QUALITY AND
STREAM FLOW DATA
USGS STREAM FLOW
GAGE

WATER QUALITY CONTROL STUDY
POWDER RIVER BASIN
KAYCEE UNIT

AREA MAP

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
Public Health Service

REGION VIII DENVER, COLORADO

FIGURE 1